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THE UNIVERSITY OF ALBERTA

THE EFFECTS OF DIFFERENT DAILY DURATIONS OF TIME IN AN ENRICHED ENVIRONMENT ON LATER MAZE BEHAVIOR IN THE MALE ALBINO RAT

by

© WILLIAM ROY WILCOX

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effects of Different Daily Durations of Time in an Enriched Environment on Later Maze Behavior in the Male Albino Rat" submitted by William Roy Wilcox in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

A number of experiments have shown that rats raised in an enriched environment (EE) perform better in a maze situation than controls raised in isolation cages. The purpose of this experiment was to compare the maze performance of five groups of male albino rats each having experienced a different daily period of time in an EE for 30 days beginning at 21 days of age: 0 hours, 1½ hours, 3 hours, 6 hours and 12 hours. When the Ss were tested starting at 51 days of age, little differences in maze behavior were seen; however, the control group (0 hours) ran significantly slower during the pretraining period, was more emotional during the early maze trials and gained less weight than rats in the EE groups. Possible reasons for the group differences are discussed.

ACKNOWLEDGEMENTS

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INTRODUCTION

The aim of this thesis is to compare the maze performance of male albino rats having experienced different daily durations of time in an enriched environment (EE). Each of the five groups of rats was subjected to its own time period of EE exposure for 30 consecutive days. At the end of this time, all Ss were given 15 spaced trials in a Lashley III maze to see if the differential upbringings resulted in significant differences in later maze behavior.

A number of experiments have been performed that show the effects of early enriched environment on later maze learning behavior. Hebb (1947) found that rats which were brought up in his home and allowed much time outside their cages performed better in a large number of fairly easy tasks than rats reared in laboratory cages. Similar results were obtained by Bingham and Griffiths (1952) and Woods (1959) when they compared maze behavior between one group having an earlier enriched environment experience and another having only restricted experience. Forgus (1955) stated that the experience from an EE only benefits the rat on certain tasks. He showed that rats having been subjected only to visual experience performed better in a maze under conditions of many visual cues than rats that had been subjected to conditions offering much visual and motor experience.

Several experimenters have attempted to find out which aspect of the EE is most beneficial to the rats in later maze behavior.

Hymovitch (1952) was led to suggest that early visual experience was very important because rats raised in mesh cages (and therefore allowed visual experience) performed equally well as those reared in free-environment boxes. The findings of Forgays and Forgays (1952) support this for they found that Ss raised in mesh cages performed better in a maze situation than Ss brought up in restricted environments. The results, however, of Denenberg and Morton (1962) are not consistent with these findings. They found that rats raised in cages with solid sides performed equally well later in a maze situation as rats raised in mesh cages. The latter only performed better than the former after the rats in the mesh cages were allowed a daily exposure to a large, complex environment.

The next section includes background information in related areas. It is important to study the effects of early enriched experience on anatomy and physiology for the findings may then lend support and give us a causal explanation to behavioral differences as a result of differential upbringings. Krech, Rosenzweig and Bennett (1962) showed a high and significant correlation between behavioral scores and cortical/subcortical ratios of brain weight in rats reared in enriched environments. Rosenzweig et al (1962) raised three groups in environments considered to be different in degrees of complexity. In general, the middle group was found to have intermediate values on cerebral measures.

Other anatomical differences have been found between rats which were raised in EEs and those raised under restricted conditions. Rosenzweig et al (cited in Rosenzweig, 1966) showed that

the diameters of capillaries in the cortex of rats reared in an enriched environment were greater than those of their littermates who were raised under impoverished conditions: it appears that the cerebral vasculature responded to an increased demand. Rosenzweig (1966) found that the number of glia cells increased in rats reared in an EE. Since these cells are believed to nourish the neurons and since neurons ramify more completely during learning processes, Rosenzweig's findings are consistent with others in supporting the environmental effect on later problem-solving behavior.

Recently, a number of experiments have shown the effects of early experience on brain biochemistry. Since one possible component of experience (i.e., memory) involves the linking together of neural units and since acetylcholine, ACh, is a transmitter substance, many of the experiments studying the effects of EE on neurochemistry are concerned with the changes in activity of ACh. Cholinesterase, ChE, which destroys ACh, is also often studied. Krech et al (1962) in a previously mentioned experiment, found within the EE group a significant correlation between the behavioral scores and the cortical/subcortical ratios of cholinesterase. These same experimenters (1960, p. 518) were led to conclude: "The more complex the environment, the lower the cortical/subcortical ratio of cholinesterase activity".

METHOD

Subjects

The Ss were 40 male albino rats of the Wistar strain obtained from Woodlyn Farms of Guelph, Ontario. At the start of the experiment they were 21 days old.

The rats were randomly divided into five groups of eight rats. Each group was regularly given one of the following number of hours daily in the enriched environment: 0, 1½, 3, 6 or 12. Respectively, the groups were designated CO, E1.5, E3, E6 and E12.

The experiment was started the day after the rats arrived so the animals were given one complete day to recover from possible effects of transportation.

Apparatus

The isolation cages (IC) were the permanent homes for the control group and the homes for the experimental groups when they were not in the enriched environment. Each IC measured 7½" by 8" by 9½". No playthings were placed in these cages. The front and bottom were of wire mesh while the walls, back and top were made of solid metal. The fronts of the cages were against a wall so that not only were the rats unable to see each other, but they were unable also to see the activities of the laboratory.

The enriched environment cages had the following dimensions: 20" by 30" by 24". In each were placed five large marbles, a plastic punching toy, a mirror with chain and a running wheel. A wire mesh ladder led up to a wooden platform at the back of each

cage. Each cage also had a small closed-off region, located near the platform, offering the rats a semi-isolated area in the EE and supplying another means for the Ss to reach the wooden platform. The front, top, back and floor of the EEs were of wire mesh while the side walls were wood.

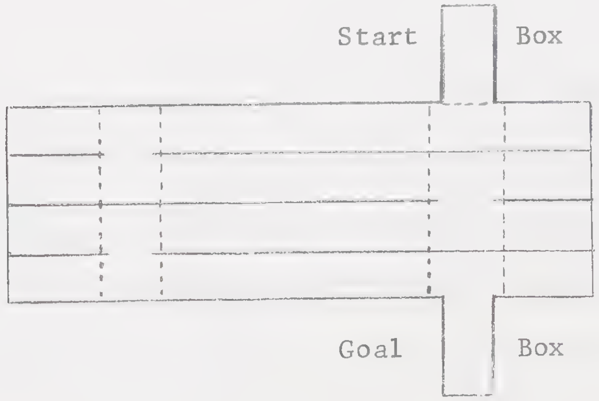
It is important to note that the term "enriched environment" includes all social interactions that occur in the EE cages as well as the back and forth movement to these cages from the isolation cages.

A straight alley was used in pretraining. It had wooden floor and walls, wire mesh top and plexi-glass guillotines on the start and goal boxes. The dimensions of the straight alley were 63" by 4".

A Lashley III maze was used for training purposes. It had wooden floor and walls, wire mesh top and plexi-glass tops on the start and goal boxes (see Fig. 1 for floor plan). The dimensions of the maze were 48" by 16", not including the start and goal boxes.

Figure 1

Lashley III Maze

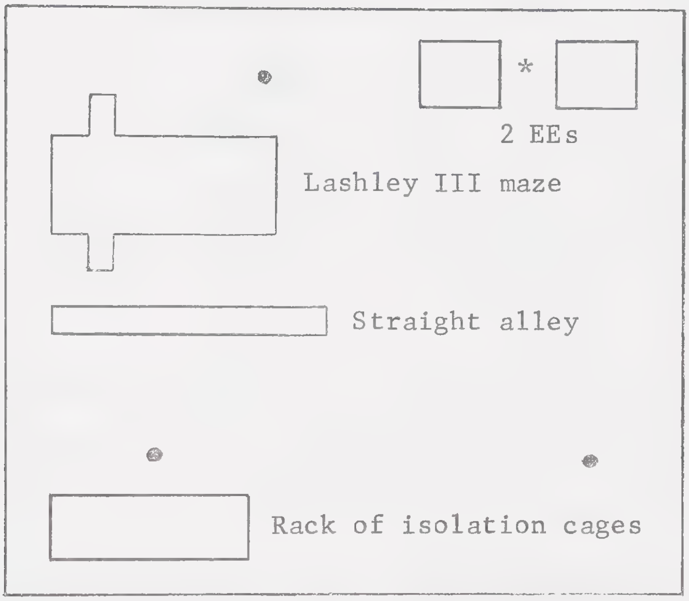


The Laboratory

Figure 2 shows the approximate arrangement of the laboratory used in this experiment. The asterisk denotes the white light source that was on from 9:00 A.M. to 9:00 P.M. Black dots represent position of the red lights that were used during the night. The dimensions of the laboratory were 19' by 17'.

Figure 2

Laboratory



Rearing

The experiment was carried out in two parts, one before the other. In the first were Groups E3 and E6; in the second, Groups CO, E1.5 and E12. Each experimental rat was placed with the other _S_s in his group in his enriched environment for his specific period of time daily for 30 days. These EE experiences always occurred

during the night period in the laboratory. Each S of the control group remained in his isolation cage for the 30 day period. Food and water were available to all Ss during this time. Table 1 shows the times the experimental rats entered and left the EEs.

Table 1

Times of Daily Periods in EE

Group	Time Ss Enter EE1 or EE2	Time Ss Leave EE1 or EE2
E1.5	5:00 A.M.	6:30 A.M.
E3	3:45 A.M.	6:45 A.M.
E6	1:15 A.M.	7:15 A.M.
E12	9:00 P.M.	9:00 A.M.

Pretraining

Pretraining started on Day 31. The seven days of this procedure are outlined in Table 2. Ss continued their regular periods of time in the EE during the pretraining and training parts of the experiment. All groups were divided into two subgroups of four rats each. Subgroups A were pretrained and trained one half way through their daily periods in the EE; Subgroups B, at the end of their periods. The pretraining and training of Subgroup A of the control group was at 5:00 A.M. and Subgroup B was at 7:00 A.M.

All Ss were deprived of food for 17 hours before pretraining and training trials. Water was always available in the isolation

cages and enriched environments. Feeding took place for one hour each day in the isolation cages.

Table 2

Pretraining Procedure

Day 31	Each _S_ received four food pellets in the goal box of the straight alley
Day 32	Same as Day 31
Day 33	Each _S_, placed in the start box of the straight alley, ran to the goal box to obtain two pellets. Three consecutive trials were run
Day 34	Same as Day 33 except four consecutive trials were run
Day 35	Same as Day 34
Day 36	Same as Day 34
Day 37	Same as Day 34

A cutoff time of 15 minutes was set during the pretraining trials. If a _S_ had not reached the goal box by this time, he was removed from the maze and taken to the cage he normally would have gone to after his trial. His next trial was on the following day. Therefore, all _Ss_ did not have 21 complete pretraining trials. In the case of these _Ss_, their data were not included in analyses of variance and graphs, unless otherwise stated. For pretraining and training speeds, the stop watch was started when the rat was placed in the maze and stopped when he started eating.

Training

Starting on Day 38, each S received one trial a day in the Lashley III maze at the times mentioned on the previous page. The reward for each trial was two pellets (each weighing 45 mg.). Figure 1 shows dotted lines drawn on the floor just after the beginning of a cul-de-sac and just before and after each door opening. If the S's hind paws crossed a line going into a cul-de-sac, a blind alley error was recorded. If the hind paws of the S crossed over a main path line while he was retracing in the maze, a retrace error was recorded. Data were collected for: (1) time required for S to get from start box to goal box, (2) number of blind alley errors, (3) number of retrace errors and (4) number of total errors (sum of (2) and (3)). There were two learning criteria: one errorless trial and two consecutive errorless trials.

Emotionality Test

The incidence of urination and/or defecation was recorded at the end of each trial for each S. These data were used as an index of emotionality.

The experimental design was a 5 x 2 factorial: 5 groups representing 5 different rearing conditions and 2 subgroups representing different pretraining and training schedules. No data were analyzed for three Ss during the pretraining period: an E6 S died, an E3 S and an E6 S were not included because of experimental error. In all cases, the experimental error was that the Ss which failed to reach the goal box by the allotted time

(15 minutes for pretraining trials and 20 minutes for training trials) were not given another trial until the next day's regular trial. Instead, they should have been put back into the maze for a complete trial later that same day.

The data from the following animals were not included in the two-way analyses of variance and the graphs: one S each from group E3, E6 and E12 because of death or injury and two CO Ss, two E3 Ss and one E12 S because of experimental error.

For the three-way analyses of variance, data for a number of Ss were not included in order to make "equal N". In two cases, the data for Ss who were not included in the two-way analyses of variance because of experimental error, were included in modified form in the three-way.

For the criteria of one errorless trial and two consecutive errorless trials, data from the following Ss were not included because of injury or death: one S each from group E3, E6 and E12.

RESULTS

The data were subjected to a repeated measures two-way analysis of variance ($\alpha = .05$). These statistical tests were received from the Division of Educational Research Services. For the dependent variable of retraces, the Environmental (differential rearing conditions) main effect was not significant, but the (15 spaced) Trials effect and the Environment x Trials interaction were (see Table 3 and Figure 3). When this interaction was tested for simple effects by Scheffé's Test, the results on Day 1 showed Group E3 having significantly more retraces than all other groups except Group E6. The latter group made significantly more retraces than Group E12. On Day 2, Group E6 made significantly more retraces than all other groups except Group E3. The latter group had significantly more retraces than Groups CO and E1.5. No significant differences were found on Days 3 to 15 (see Appendix A).

For the dependent variable of total errors, only the Trials effect was significant (see Table 4 and Appendix B).

For the dependent variables of blind alley errors and speed (100/time in seconds), again only the Trials effect was significant (see Table 5 and Appendix C and Table 6 and Appendix D).

A one-way analysis of variance was run for each of the criteria of one errorless trial and two consecutive errorless trials. Neither analysis was significant ($F = .63$, $df = 4/32$, $p. > .10$ and $F = .93$, $df = 4/32$, $p. > .10$ for the criteria of one errorless trial and two consecutive errorless trials, respectively). The variability within

Table 3

Two-Way Analysis of Variance with Repeated Measures

Retraces

Source of Variation	df	MS	F	P
Environment	4	187.089	2.304	NS
Error (between)	27	81.187		
Trials	14	1325.278	28.518	.001
Envir. x Tri.	56	64.521	1.388	.05
Error (within)	378	46.472		

Table 4

Two-Way Analysis of Variance with Repeated Measures

Total Errors

Source of Variation	df	MS	F	P
Environment	4	352.062	1.936	NS
Error (between)	27	181.888		
Trials	14	3492.270	37.196	.001
Envir. x Tri.	56	108.118	1.152	NS
Error (within)	378	93.888		

Figure 3

Mean Retraces by Trials

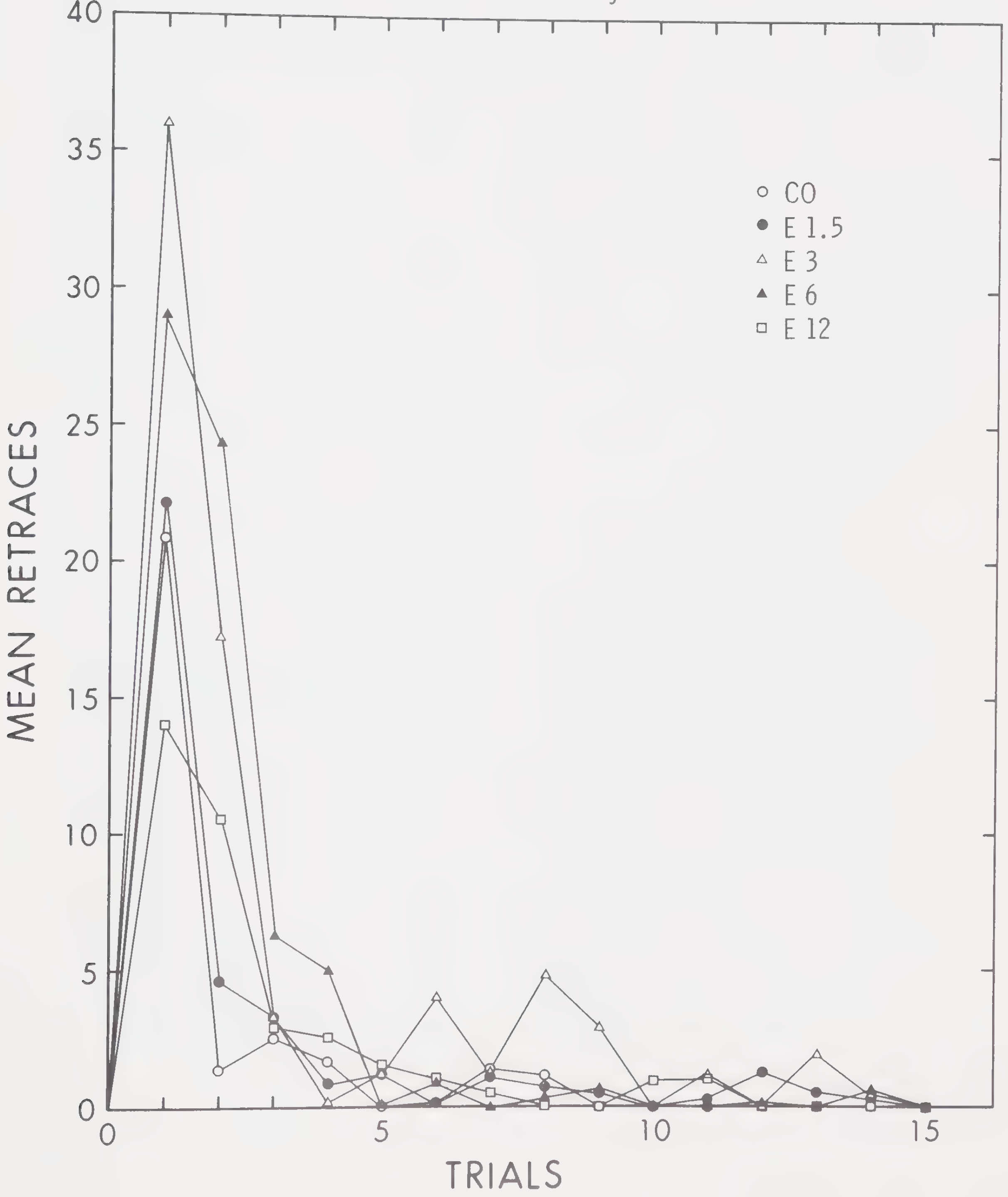


Table 5

Two-Way Analysis of Variance with Repeated Measures

Blind Alley Errors

Source of Variation	df	MS	F	P
Environment	4	28.352	1.219	NS
Error (between)	27	23.249		
Trials	14	516.455	53.363	.001
Envir. x Tri.	56	8.469	0.875	NS
Error (within)	378	9.678		

Table 6

Two-Way Analysis of Variance with Repeated Measures

Speed

Source of Variation	df	MS	F	P
Environment	4	55.112	0.279	NS
Error (between)	27	197.484		
Trials	14	790.939	65.946	.001
Envir. x Tri.	56	15.813	1.318	NS
Error (within)	378	11.994		

the groups was also analyzed by a simple F test. No significant differences were found for the criterion of two consecutive errorless trials. For one errorless trial, Group E12 was found to be significantly less variable than all other groups. Group E6 was significantly less variable than Group E3.

A three-way analysis of variance was run to determine if Ss who were pretrained and trained in the middle of their daily EE exposure (Subgroups A) performed significantly differently in the maze than those Ss who had their pretraining and training at the end of their daily EE exposure (Subgroups B). As can be seen in Appendices E, F, G and H, no significant differences were found between subgroups or in any interactions involving subgroups. Consistent with the two-way analysis of variance, the Environmental main effects for all four dependent variables were insignificant and all four dependent variable's Trials effects were significant. The only difference was in the Environmental x Trials interaction for the dependent variable of total errors: this was insignificant in the two-way analysis of variance but significant in the three-way. More emphasis is placed on the two-way analysis of variance results as more Ss were included in this analysis and no Ss were included with an experimental error as was not true in the three-way analysis.

The results of a two-way analysis of variance with repeated measures on pretraining speeds are found in Table 7. In all three measures of Environmental main effect, Trials effect and Environment x Trials interaction, significant differences were found. A plot

of these data is found in Figure 4. When Scheffé's Test for simple effects was applied to these data, significant differences were found between groups starting on Trial 8. In most cases, the control group performed significantly slower than all other groups (see Appendix I for details).

Table 7

Two-Way Analysis of Variance with Repeated Measures

Pretraining Speed

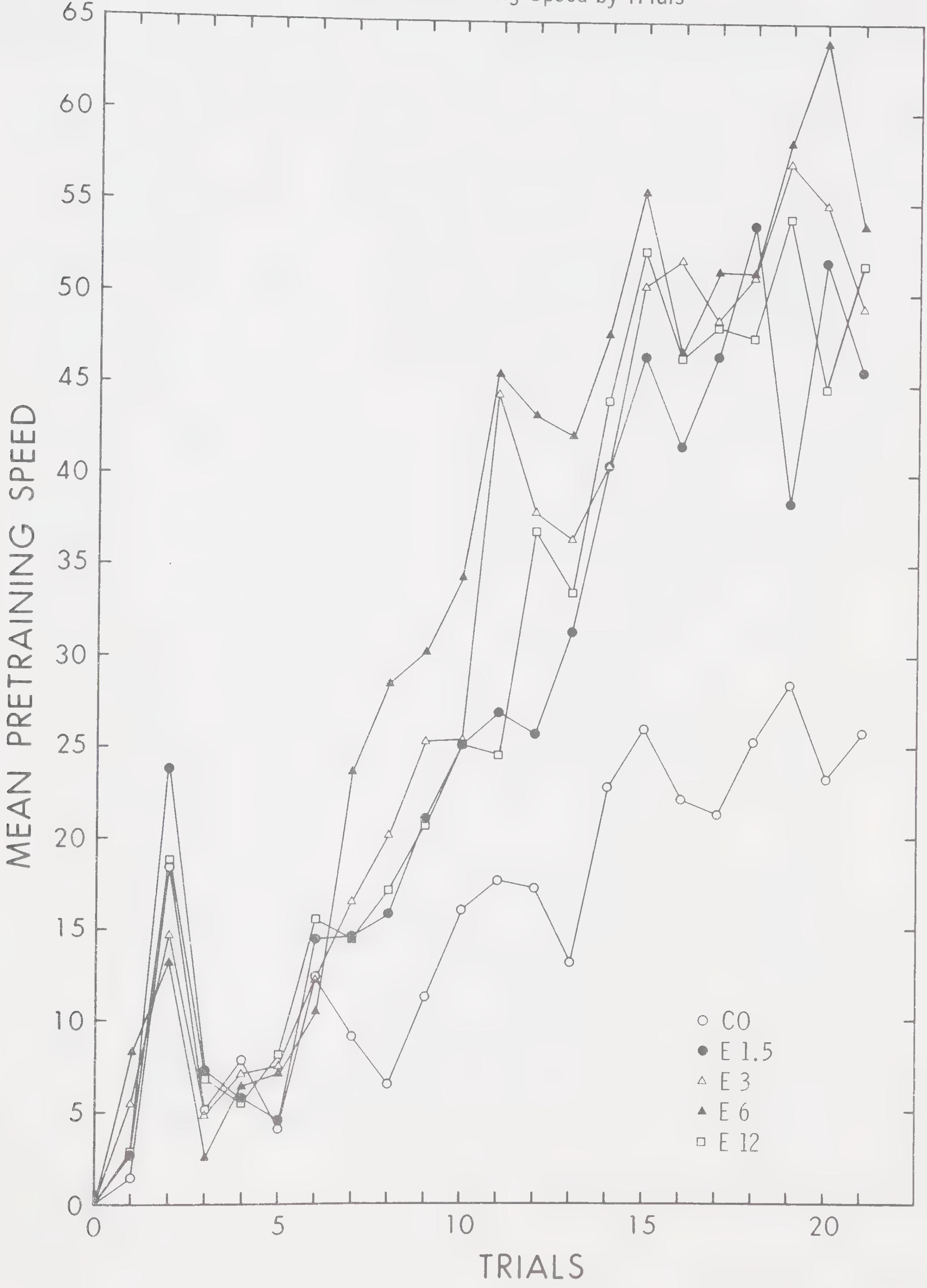
Source of Variation	df	MS	F	P
Environment	4	7678.934	10.851	.001
Error (between)	32	707.701		
Trials	20	8957.676	97.400	.001
Envir. x Tri.	80	267.146	2.905	.005
Error (within)	640	91.968		

A three-way analysis of variance was run for the pretraining speed (see Appendix J). The results were consistent with the two-way analysis. No significant differences were found between subgroups or in any interactions involving subgroups.

Table 8 shows the results of the emotionality test. After the second day of training trials, no urinations and/or defecations occurred. It can be seen that longer daily periods in an enriched environment favour a decrease in emotionality with this effect strongest on the first few days in the apparatus. These data were

Figure 4

Mean Pretraining Speed by Trials



subjected to a two-way analysis of variance (see Table 9). The results show a significant Environmental (differential rearing conditions) main effect and a significant Day effect.

Table 8

Emotionality Test

Day of Pre-training	Group	No. of Rats Urinating	No. of Rats Defecating	No. of Rats Urinating and Defecating	Sum of Rats Urinating and/or Defecating
1	CO	3	0	3	6
	E1.5	1	1	2	4
	E3	1	1	0	2
	E6	1	0	0	1
	E12	0	0	0	0
2	CO	4	0	1	5
	E1.5	1	1	0	2
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0
3	CO	1	0	2	3
	E1.5	0	0	1	1
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	1	0	1
4	CO	1	0	2	3
	E1.5	0	0	0	0
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0
5	CO	1	1	1	3
	E1.5	1	0	0	1
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0

Emotionality Test (concluded)

Day of Pre-training	Group	No. of Rats Urinating	No. of Rats Defecating	No. of Rats Urinating and Defecating	Sum of Rats Urinating and/or Defecating
6	CO	0	2	1	3
	E1.5	0	0	0	0
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0
7	CO	1	0	1	2
	E1.5	0	0	0	0
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0
Day of Training	**Group**	**No.of Rats Urinating**	**No. of Rats Defecating**	**No. of Rats Urinating and Defecating**	**Sum of Rats Urinating and/or Defecating**
1	CO	2	0	0	2
	E1.5	0	0	0	0
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0
2	CO	1	0	1	2
	E1.5	0	0	0	0
	E3	0	0	0	0
	E6	0	0	0	0
	E12	0	0	0	0

The mean weights of the groups in the second part of the experiment are found in Table 10. No similar data are available for Ss used in the first part. Experience in an EE appears to lead to greater weight in male albino rats than does experience in regular laboratory cages. The data for Day 55 were subjected

to a simple analysis of variance and were found to be significantly different (_F_ = 8.37, _df_ = 2/20, _p_. $<$ .005).

Table 9

Two-Way Analysis of Variance with Repeated Measures

Emotionality Test

Source of Variation	df	MS	F	P
Environment	4	2.712	5.011	.005
Error (between)	32	0.541		
Days	8	0.275	3.153	.005
Envir. x Days	32	0.066	0.756	NS
Error (within)	256	0.087		

Table 10

Mean Weights of Groups
(in grams)

	Group CO	Group E1.5	Group E12
Day 1	50.6	51.0	50.0
Day 19	151.5	161.6	157.3
Day 37	168.2	201.0	198.0
Day 46	155.3	200.3	195.0
Day 55	177.5	217.4	216.3

DISCUSSION

The results of this experiment show no significant Environmental main effects for any of the four dependent variables. The only significant Environment x Trials interaction is for the dependent variable of retraces. The results on Day 1 show Group E3 having significantly more retraces than all other groups except Group E6. The latter group made significantly more retraces than Group E12. On Day 2, Group E6 made significantly more retraces than all other groups except Group E3. The latter group had significantly more retraces than Groups CO and E1.5. No significant differences were found for Days 3 to 15. This may be partially the result of the superior performance of one control S who made no errors after the first day of training.

This finding of few significant differences between rats reared under impoverished conditions and rats raised in enriched environment conditions is quite surprising when compared to data from other experiments (Hebb, 1947; Forgays & Forgays, 1952; Bingham & Griffiths, 1952; Hymovitch, 1952 and Krech, Rosenzweig and Bennett, 1962).

It is in agreement, however, with the results of Reid, Gill and Porter (1968) who, after raising one group of rats in an enriched environment and another in isolation cages, found no significant differences between the maze behavior of the two groups.

Woods, Fiske and Ruckelshaus (1961) found that Ss raised in restricted environments were actually able to surpass the performance of rats raised under enriched environment conditions if the former were deprived of food for a greater period of time. This seems to suggest that modification of motivation might bring the control

S's maze performance closer to that of the experimental S's.

There are a number of procedural differences between other experiments and the present one that should be discussed since they may account for the absence of the typically-found improved performance in rats with EE experience.

Perhaps the most important reason for the present results is that all training trials were spaced at one trial per day for 15 days. Shandro (1969, p. 45) states that "the environmental main effect appears to be due to the fact that the enriched animals are capable of more rapid consolidation which is necessary in the massed practice situation than the restricted animals are". He cites Thomson, McGaugh, Smith, Hudspeth and Westbrooke (1961, p. 69): the difference in performance is in "post trial consolidation of neural processes mediating maze behavior.". Therefore, animals raised under isolated conditions show a decrement in behavior, and conversely EE animals show facilitation by comparison to the isolated animals, only when trials are massed together. Since the trials in the present experiment were spaced, the finding of no significant differences between groups is consistent with this view. Also, the finding of significant differences during the massed trials of pretraining supports this hypothesis.

In the present experiment, all exposures to the enriched environments took place between 9:00 P.M. and 9:00 A.M. during which time the lights were out. This procedure was followed because rats are nocturnal animals and any attempt to shift them to diurnal

activity would have introduced another variable. In the introduction it was mentioned that early visual experience was important to later problem-solving behavior. It is possible that since all experimental groups were not allowed full visual use in the EE, their benefits from this environment might be greatly reduced. However, other benefits still were present in the form of general motor activity and social interaction.

Most of the experiments studying the effects of enriched environments have the rats staying in the EE 24 hours a day for a given period of time. The only exception to my knowledge was the previously mentioned experiment by Denenberg and Morton (1962). They raised two groups of rats in small mesh cages; however, one group was given 2½ hours daily in an enriched environment. This group made fewer error scores on later maze tests. In the present experiment there is a variable which is very difficult to account for: the daily back and forth movement between the EE and the isolation cages. It is possible that frustration could arise more easily in the groups experiencing low duration daily EE exposures as they may be taken away from the enriched environments when they are still very active. However, groups which have been in the EE for many hours may actually become bored (compared to the experimental groups subjected to low daily durations of EE exposure) and hence would be less reluctant to leave. This is further complicated by factors working in the opposite direction. Group E12 may not be as frustrated as other experimental groups but since Group E12 Ss

spent much time resting in the EE, the overall benefits from the daily enriched environment experience could be less than what one might expect.

Although some experiments involving rats in an EE for 30 days showed these Ss benefitted from this environment (Bingham & Griffiths, 1952 and Denenberg & Morton, 1962), a number of the previously discussed experiments had the experimental groups in the EE for 60 days or more (Forgays & Forgays, 1951 and Woods, 1959). An important point here might be the possibility of a "critical period". In a previously mentioned experiment by Woods (1959), the author stated that rats which were in isolation until 66 days of age and then placed in an enriched environment, performed better in a maze situation at maturity than controls that spent the whole period of time in isolation. Woods suggests that the former group's free environment experience took place during a "critical period" of development. He cites Eingold (1956) as saying that a critical period for this type of experience is between 46 and 65 days of age. Although the Ss were 66 days old when they entered the free environment, they were exposed to the training apparatus between the ages of 54 and 65 days. It is possible that the rats used in the present experiment were removed from the EE before a critical period was reached. If this were the case, the experimental groups wouldn't necessarily give a better performance than the controls in the maze.

The period of food deprivation was slightly less in the present experiment than in most experiments of this type. A period of 17

hours was required because of the setup of subgroups, and the fact that food could not be placed in the EE during pretraining and training. Although food deprivation was the same for all the groups in this experiment, in comparison with other experiments the difference might have some effect as was shown by Woods et al (1961).

Some of the experiments have had the experimental _S_s caged in individual cages during the pretraining and training periods. In the present experiment, the daily exposures in the EE were still continued. This prodedure might affect their performance in a maze for if the _S_s were denied exposure to the EE and only allowed to run the maze, the anticipation of physical and visual activities which the rats normally would have displayed in the EE might affect their maze performance. It is difficult to know the effects of this procedure but it is possible if the _S_s were housed separately in small cages during pretraining and training, they may find the testing apparatus relatively complex and hence inducive to exploration. Even after a period of time in an enriched environment, _S_s housed in small cages during pretraining and training may become accustomed to a lower level of stimulation. The results might be that these _S_s may not perform as well as experimental _S_s (that are continuing their EE exposures) in a maze situation. This is discussed more fully later on. Woods, Ruckelshaus and Bowling (1960) housed the experimental _S_s in the EE and the control _S_s in the restricted conditions for the whole time of the experiment. They found the experimental group performed significantly better in a maze situation. Reid, Gill and Porter (1968) housed all _S_s

individually during pretraining and training trials. They found no significant differences between groups in maze behavior. Perhaps the experimental Ss were becoming accustomed to a lower level of stimulation (i.e., closer to that of the control's) and hence performing comparably to the control group.

Inconsistency in results from a number of experiments might be reduced if there was a greater similarity in maze structure. Littman and Hsieh (1964) found that rats allowed to run three different length alleys, 11", 22" and 33", showed least general activity in the shortest alley. Kennedy and Stone (1936) mentioned the possibility of the cross-sectional area of the alley being important. Therefore, if exploration is an important factor in maze learning, unless there is consistency in maze structure, the related experiments may not bring consistent results. In previously mentioned experiments, Hebb-Williams mazes and closed field tests were often used; whereas, in the present study, a Lashley III maze was the testing apparatus.

The enriched environments used in a number of experiments are somewhat different. Not only do some include objects that others don't, but some house a greater number of rats than others. It is likely that the socialization aspect of early EE experience is very important to later maze behavior. If some enriched environments offer crowded conditions, the rats may become more frustrated and hence the early EE experience may not prove beneficial for later performance in a maze situation. Hebb (1947) allowed the experimental rats to spend much of their time outside their cages

at the experimenter's home. Frustration from crowding would not be likely under such conditions. Bingham and Griffiths (1951) used 16 rats in the experimental group, but instead of being kept in cages, they were left open in a 6' by 9' room. Both of these experiments showed the experimental groups performed significantly better in a maze situation than control groups. Reid, Gill and Porter (1968), whose results were more similar to the present experiment's results, housed 8 to 10 Ss in EE cages.

The socialization aspect is a very difficult one to analyze. Perhaps "optimum stimulation" should be considered. Rats raised in an EE are accustomed to a level of stimulation much greater than that of the control group. The latter, when in the maze situation, may favour avoidance in an approach-avoidance conflict. Much fighting was observed in the EE cages. The result of this might be that these Ss become accustomed to "fear-provoking situations" and hence (in contrast to the control Ss) favour approach in an approach-avoidance conflict.

Several non-learning measures were significantly affected by the rat's rearing condition. For the measure of pretraining speed of running, the control group was significantly slower than any of the experimental groups. It is possible that emotionality is an important factor here. Table 9 shows that Group CO was the most emotional group. Usually, as emotionality increases, performance in a maze is poorer. Likely, this is mainly because an increase in emotionality causes rats to freeze (or move more hesitantly) in a maze situation. The control group's relatively

poor performance in pretraining might be largely a result of freezing. Another possible explanation is given by Billingslea (1941, p. 76-77): "In strange situations, the performance of the emotional animal is inferior to that of the less emotional animal, because fear inhibits the expression of adequate adjustments". By the beginning of training, the groups' emotionalities were becoming more comparable and so were their performances in the maze. This is not consistent with the fact that during pretraining the control group's emotionality decreased yet its running speed became slower in relation to the experimental groups' (although it became faster than its own previous trials'). However, this is consistent with the hypothesis that rats raised in an EE show superiority in mazes when the trials are massed (as they were during this part of the pretraining).

According to the hypothesis set forth by Zimbardo and Montgomery (1957), rats with enriched environment experience perform better in a maze because of a relatively decreased "exploratory drive". These Ss find the testing apparatus less inducive to exploration than the controls. This is because "complexity" is inducive to exploration, and for the control group the maze appears more complex in comparison to their home environment. Although the present experiment's training results are not consistent with this hypothesis, the latter is supported by the pretraining results. Procedural differences outlined previously could account for the inconsistency here.

There appears to be several possible explanations concerning the control group's pretraining behavior. Is the control group's relatively poor pretraining performance a result of increased "exploratory drive" resulting from the novelty and/or complexity of the alley situation or a result of freezing (or, at least, moving hesitantly) from increased emotionality? In this experiment, my observations tend to support both. The Ss seemed to spend a great deal of time exploring, but the times of some trials were so long because movements were made so cautiously. Another possibility is a difference in the groups' "escape behavior". Although exploratory behavior may be difficult to differentiate from escape behavior, it appeared the former dominated because the parts of the maze which were more likely to offer an escape (i.e., small wire mesh openings near the top of the start and goal boxes) were not explored any more intensely than the other parts. Probably there are many factors involved with complex interactions, and the resulting overt behavior shows many individual differences.

The breakdown of groups into subgroups was done to see if there was a difference in performance depending on whether training occurred one half way through the daily EE exposure (Ss returning to EE after training) or at the end of it (Ss going to individual cages after training). It was thought that the cycles of activity which the groups set up in the EE might affect their performance. Also, perhaps the anticipation of physical activity and social interplay following the trial, instead of returning to isolation cages, could have some effect on their maze performance. Perhaps

as a result, however, of individual differences and a small sample size, no significant differences were found between subgroups in maze performance (see Appendices E, F, G, H and J).

The weights of the Ss were affected by their enriched experience. Weininger (1954) showed that rats that had been gentled weighed significantly more than control Ss. This gain in weight in the present experiment by the experimental groups was probably due to more exercise and hence a greater food requirement. Also, social facilitation probably had a significant role. A rat in an isolation cage may be deprived of food for the same period of time as a rat in an EE; but while the former may not be sufficiently motivated to initiate eating, the latter may do so partially as a result of watching other rats eat. Denenberg (1952, p. 503) suggested the possibility of social facilitation when he showed that control Ss hoarded significantly more than Ss reared in EEs. He felt that the experimental Ss hoarded less than control Ss because of the "social facilitation of eating under group conditions".

As previously mentioned, the emotionality test also showed differences among the groups. Most experiments studying emotionality consider the number of urinations and defecations by the Ss an index of their emotionality. Hall (1934, p. 492) defined emotional defecation and urination as "that defecation and urination which ceased upon repeated experience with the situation that originally evoked it". He demonstrated that these were valid measures of individual differences in emotionality. However, this is not fully agreed upon (Bindra & Thompson, 1953). Concerned specifically with

fearfulness, they stated that the coefficients of correlation between emotional elimination (defecation and urination in a strange situation) and fearfulness (failure to eat when hungry) were not significantly different from zero; and hence the former was not a valid measure of the latter.

In summary, at the end of 30 consecutive days of different upbringings, the five groups of rats were subjected to a period of pretraining followed by 15 spaced training trials. Starting on Trial 8 of the 21 pretraining trials, the control group generally performed significantly slower than the experimental groups.

The training trials showed few significant differences between groups. There were no significant Environmental main effects for any of the four dependent variables.

There were no significant differences between groups for either of the criteria of one errorless trial or two consecutive errorless trials. However, for the criterion of one errorless trial, Group E12 was significantly less variable than all other groups.

It was seen that Ss with enriched environment experience weigh significantly more than Ss without this experience.

The emotionalities of the groups were significantly different; the control group being the most emotional. All groups became less emotional during pretraining and by the end of Day 2 of training, no urinations or defecations occurred. By this time, the similarity in emotionalities may be an important factor in the similarity of training trials for all groups.

Perhaps the most important reason for the present results is that the training trials were spaced at one trial a night. It has been suggested that massed trials bring out the differences in maze behavior between Ss with enriched environment experience and control Ss. The present pretraining and training results are consistent with this hypothesis.

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APPENDIX A

Scheffé's Test for Simple Effects for Retraces

$$F = \frac{(\bar{X}_1 - \bar{X}_2)^2}{MS_{error}(n_1 + n_2)/n_1 n_2}$$

where $MS_{error} = 46.5$ and

$n_1 = 6$, $n_2 = 8$, $n_3 = 5$, $n_4 = 7$ and

$n_5 = 6$

$df_1 = (k - 1) = (5 - 1) = 4$

$df_2 = (N - k) = (32 - 5) = 27$

F required for significance at .10 level with $df_1 = 4$ and $df_2 = 27$ is 2.17

$F' = (k - 1)F = (4)2.17 = 8.68$

Day 1 Tabulations

(underlined figures indicate significant differences)

	CO	E1.5	E6	E3
E12	3.0	4.8	$\underline{15.6}$	$\underline{28.3}$
CO		0.12	4.7	$\underline{13.5}$
E1.5			3.8	$\underline{12.8}$
E6				3.1

Day 1 Results

(from least to most retraces)

$\underline{\text{E12 \quad} \underline{\text{CO \quad E1.5}}\text{ \quad}}\text{ E6 \quad E3}$

E12 CO E1.5 E6 E3

Scheffé's Test for Retraces (concluded)

Day 2 Tabulations

	E1.5	E12	E3	E6
CO	0.85	5.7	14.8	37.1
E1.5		2.7	10.5	31.4
E12			2.5	13.0
E3				3.3

Day 2 Results

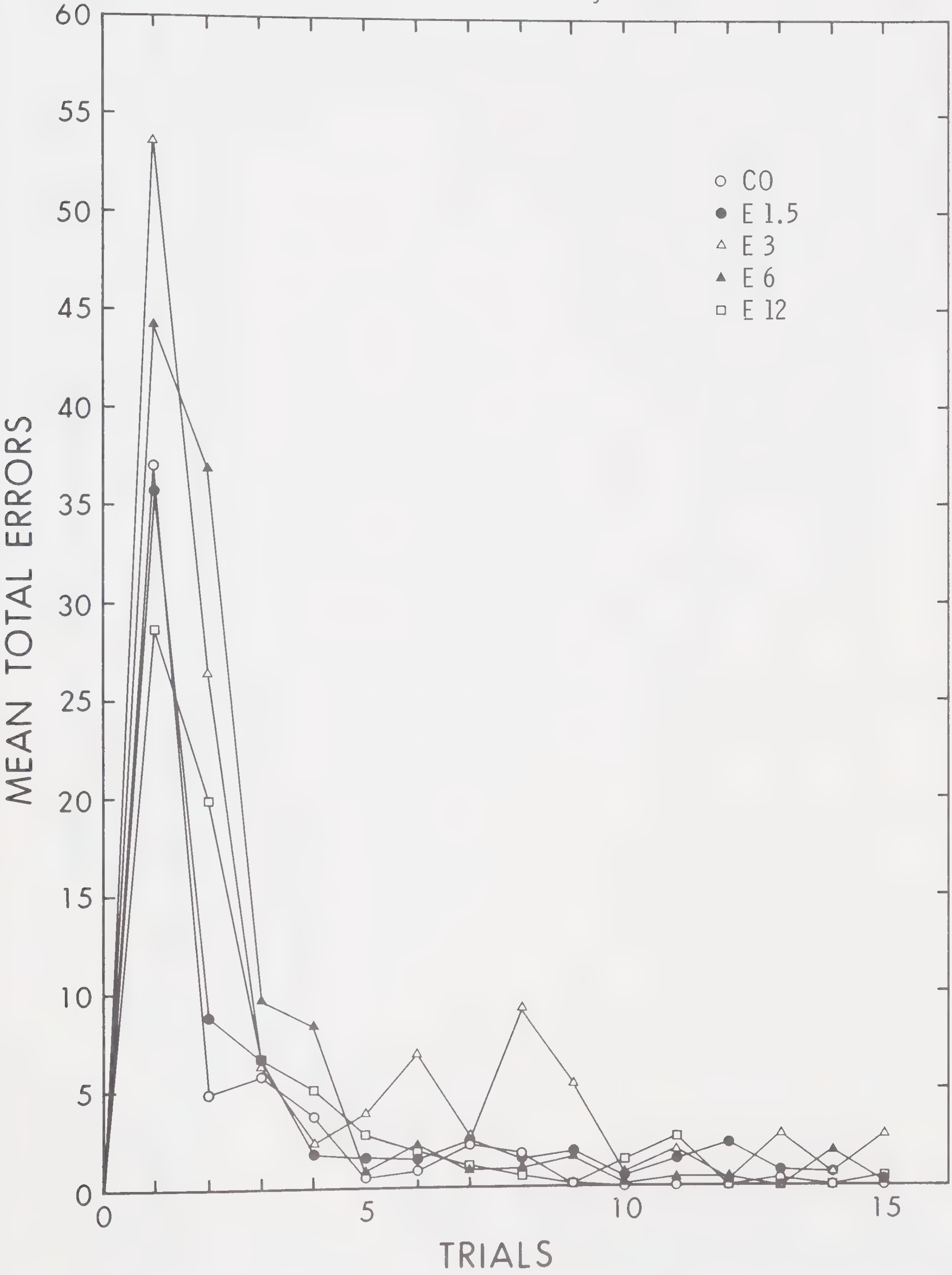
CO E1.5 E12 E3 E6

Days 3 to 15 Results
(not significant)

CO E1.5 E3 E6 E12

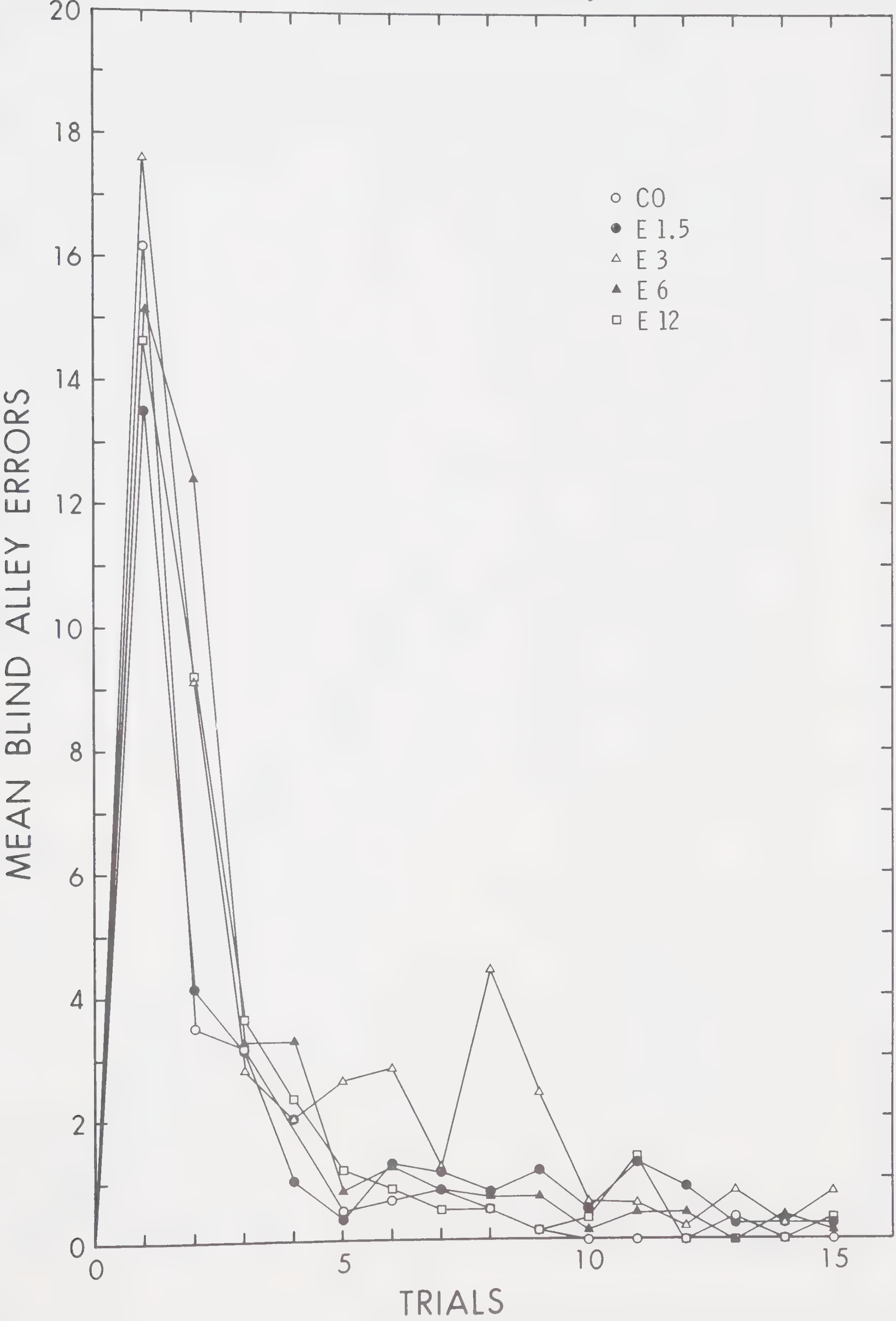
APPENDIX B

Mean Total Errors by Trials



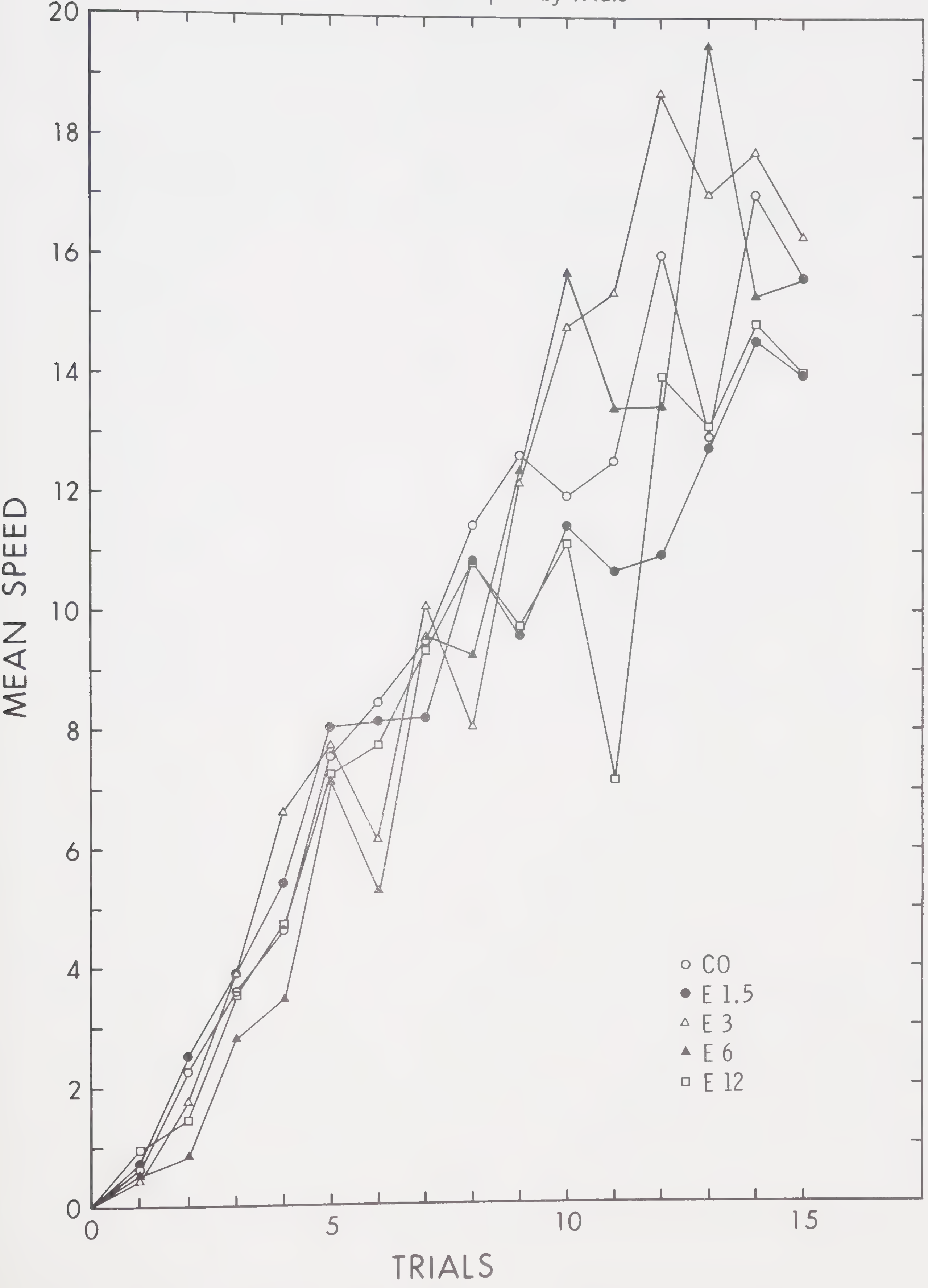
APPENDIX C

Mean Blind Alley Errors by Trials



APPENDIX D

Mean Speed by Trials



APPENDIX E

Three-Way Analysis of Variance with Third Factor Repeated

Retraces

Source of Variation	df	MS	F	P
Environment	4	202.081	2.26	NS
Subgroups	1	98.938	1.11	NS
Envir. x Sub.	4	75.297	0.84	NS
Error (between)	20	89.240		
Trials	14	1442.649	27.64	.001
Envir. x Tri.	56	94.276	1.81	.005
Sub. x Tri.	14	25.697	0.49	NS
Envir. x Sub. x Tri.	56	59.130	1.13	NS
Error (within)	280	52.201		

APPENDIX F

Three-Way Analysis of Variance with Third Factor Repeated

Total Errors

Source of Variation	df	MS	F	P
Environment	4	354.656	1.72	NS
Subgroups	1	237.621	1.15	NS
Envir. x Sub.	4	189.619	0.92	NS
Error (between)	20			
Trials	14	3788.248	34.12	.001
Envir. x Tri.	56	161.571	1.46	.05
Sub. x Tri.	14	72.304	0.65	NS
Envir. x Sub. x Tri.	56	130.221	1.17	NS
Error (within)	280	111.031		

APPENDIX G

Three-Way Analysis of Variance with Third Factor Repeated

Blind Alley Errors

Source of Variation	df	MS	F	P
Environment	4	23.931	0.87	NS
Subgroups	1	29.902	1.08	NS
Envir. x Sub.	4	28.181	1.02	NS
Error (between)	20	27.607		
Trials	14	557.337	45.25	.001
Envir. x Tri.	56	11.374	0.92	NS
Sub. x Tri.	14	13.917	1.13	NS
Envir. x Sub. x Tri.	56	14.622	1.19	NS
Error (within)	280	12.316		

APPENDIX H

Three-Way Analysis of Variance with Third Factor Repeated

Speed

Source of Variation	df	MS	F	P
Environment	4	81.250	0.40	NS
Subgroups	1	7.410	0.04	NS
Envir. x Sub.	4	255.512	1.25	NS
Error (between)	20	204.087		
Trials	14	771.404	63.25	.001
Envir. x Tri.	56	16.079	1.32	NS
Sub. x Tri.	14	7.757	0.64	NS
Envir. x Sub. x Tri.	56	11.696	0.96	NS
Error (within)	280	12.196		

APPENDIX I

Scheffé's Test for Simple Effects for Pretraining Speed

$$F = \frac{(\bar{X}_1 - \bar{X}_2)^2}{MS_{error}(n_1 + n_2)/n_1 n_2}$$

where $MS_{error} = 91.9$ and $n_1 = 8$, $n_2 = 8$, $n_3 = 7$, $n_4 = 6$ and $n_5 = 8$

$df_1 = (k - 1) = (5 - 1) = 4$

$df_2 = (N - k) = (37 - 5) = 32$

F required for significance at .10 level with $df_1 = 4$ and $df_2 = 32$ is 2.13

$F' = (k - 1)F = (4)2.13 = 8.52$

Trials 1 to 7 Results
(not significant)

$\underline{\text{CO} \quad \text{E1.5} \quad \text{E3} \quad \text{E6} \quad \text{E12}}$

Trial 8 Tabulations

(underlined figures indicate significant differences)

	E1.5	E12	E3	E6
CO	3 8	5.1	7.5	$\underline{17.9}$
E1.5		0.09	0.72	5.8
E12			0.32	4.6
E3				2.4

Trial 8 Results

(from slowest to fastest time required to reach goal box)

CO E1.5 E12 E3 E6

Trial 9 Tabulations

	E12	E1.5	E3	E6
CO	3.9	4.4	8.2	13.2
E12		0.01	0.90	3.2
E1.5			0.68	2.9
E3				0.74

Trial 9 Results

CO E12 E1.5 E3 E6

Trial 10 Tabulations

	E1.5	E3	E12	E6
CO	3.6	3.4	3.8	12.5
E1.5		0.00	0.00	3.2
E3			0.00	2.9
E12				3.0

Trial 10 Results

CO E1.5 E3 E12 E6

Trial 11 Tabulations

	E12	E1.5	E3	E6
CO	2.0	3.8	28.5	29.3
E12		0.27	15.8	16.8
E1.5			12.0	13.0
E3				0.08

Trial 11 Results

CO E12 E1.5 E3 E6

Trial 12 Tabulations

	E1.5	E12	E3	E6
CO	3.1	16.9	17.4	25.4
E1.5		5.5	6.1	11.6
E12			0.00	1.5
E3				1.0

Trial 12 Results

CO E1.5 E12 E3 E6

Trial 13 Tabulations

	E1.5	E12	E3	E6
CO	14.2	17.9	21.9	31.4
E1.5		0.18	1.1	4.4
E12			0.34	2.8
E3				1.1

Trial 13 Results

CO E1.5 E12 E3 E6

Trial 14 Tabulations

	E3	E1.5	E12	E6
CO	12.6	13.7	19.7	23.1
E3		0.00	0.56	1.9
E1.5			0.53	1.9
E12				0.48

Trial 14 Results

CO E3 E1.5 E12 E6

Trial 15 Tabulations

	E1.5	E3	E12	E6
CO	17.6	23.2	29.2	31.8
E1.5		0.59	1.5	3.1
E3			0.16	0.99
E12				0.41

Trial 15 Results

CO E1.5 E3 E12 E6

Trial 16 Tabulations

	E1.5	E12	E6	E3
CO	16.1	25.7	22.4	35.4
E1.5		0.22	1.0	4.2
E12			0.00	1.1
E6				0.18

Trial 16 Results

CO E1.5 E12 E6 E3

Trial 17 Tabulations

	E1.5	E12	E3	E6
CO	27.4	31.2	30.1	32.9
E1.5		0.13	0.18	0.79
E12			0.01	0.31
E3				0.09

Trial 17 Results

CO E1.5 E12 E3 E6

Trial 18 Tabulations

	E12	E3	E6	E1.5
CO	18.6	26.8	24.8	35.3
E12		1.0	0.97	2.7
E3			0.00	0.32
E6				0.27

Trial 18 Results

CO E12 E3 E6 E1.5

Trial 19 Tabulations

	E1.5	E12	E3	E6
CO	4.4	29.2	33.7	33.6
E1.5		10.7	14.2	14.7
E12			0.36	0.65
E3				0.05

Trial 19 Results

CO E1.5 E12 E3 E6

Trial 20 Tabulations

	E12	E1.5	E3	E6
CO	20.3	35.3	40.5	61.8
E12		2.1	4.1	13.6
E1.5			0.39	5.5
E3				2.9

Trial 20 Results

CO E12 E1.5 E3 E6

Trial 21 Tabulations

	E1.5	E3	E12	E6
CO	17.1	21.9	29.2	29.5
E1.5		0.47	1.6	2.6
E3			0.30	0.85
E12				0.18

Trial 21 Results

CO E1.5 E3 E12 E6

Summary of Results for Scheffé's Test for Pretraining Speed

Trials 1 to 7 (NS)	CO	E1.5	E3	E6	E12
Trial 8	CO	E1.5	E12	E3	E6
Trial 9	CO	E12	E1.5	E3	E6
Trial 10	CO	E1.5	E3	E12	E6
Trial 11	CO	E12	E1.5	E3	E6
Trial 12	CO	E1.5	E12	E3	E6
Trial 13	CO	E1.5	E12	E3	E6
Trial 14	CO	E3	E1.5	E12	E6

Trial 15	CO	E1.5	E3	E12	E6
Trial 16	CO	E1.5	E12	E6	E3
Trial 17	CO	E1.5	E12	E3	E6
Trial 18	CO	E12	E3	E6	E1.5
Trial 19	CO	E1.5	E12	E3	E6
Trial 20	CO	E12	E1.5	E3	E6
Trial 21	CO	E1.5	E3	E12	E6

APPENDIX J

Three-Way Analysis of Variance with Third Factor Repeated

Pretraining Speed

Source of Variation	df	MS	F	P
Environment	4	5947.281	8.08	.05
Subgroups	1	32.125	0.04	NS
Envir. x Sub.	4	895.109	1.22	NS
Error (between)	20	736.331		
Trials	20	7784.852	88.94	.001
Envir. x Tri.	80	238.381	2.72	.05
Sub. x Tri.	20	89.456	1.02	NS
Envir. x Sub. x Tri.	80	91.027	1.04	NS
Error (within)	400	87.527		

APPENDIX K

Table of Results for Criterion of One Errorless Trial

Group	Mean Day Criterion Met
CO	7.3
E1.5	6.8
E3	9.3
E6	8.0
E12	5.7

APPENDIX L

Table of Results for Criterion of Two Consecutive Errorless Trials

Group	Mean Day Criterion Met
CO	10.5
E1.5	10.8
E3	11.7
E6	10.6
E12	9.0

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